End User Computing GHG Emissions

A Px³ Research Paper for IGEL

Abstract

End user computing (EUC) is recognised as a high contributor to environmental pollution and climate change directly and indirectly causing as much as 2.5% of global emissions [1]. One half of EUC device carbon footprint is attributed to manufacturing and use phase energy (UPE) consumption [1]. The associated pollution is generated by activities such as raw material acquisition, manufacturing and assembly plus the electricity required to power popular devices such as notebooks, desktop computers and tablets. As identified by this and associated research [2], the environmental impact is highly variable due to differing materials used during embodiment and the range of energy efficiency experienced between EUC devices within the same category. The second half of the carbon footprint is created by related emissions such as commuting to access IT (CAIT). To determine specific levels of impact, this empirical lifecycle assessment (LCA) research examines the positive consequence of three specific IT sustainability strategies. These include displacement, thin client enabled remote working and the adoption of energy efficient computers. The results highlight that by repurposing existing devices rather than purchasing new computers reduces carbon footprint by 60%. Remote working solutions enabled by thin client computers reduce scope 3 emissions by 40% and energy efficiency is improved by between 22-49% depending on the solution and approach.

Introduction

Since the Industrial Revolution, human polluting activity known as anthropogenic interference has already caused 1.0°C of global warming [3]. A further increment to 1.5°C will be reached between 2030 and 2052 if emissions increases continue at the current rate [3]. However, scientists calculate that reaching and sustaining net zero global anthropogenic CO_2 emissions by mid-century, will halt global warming on a multi-decadal scale and temperature gains will begin to peak [3]. To achieve this goal, it is calculated that the world cannot rely solely on key greenhouse gas abatement strategies, such as vehicle electrification and renewable energy transition [4, 5, 6, 7]. This is because evidence indicates that the rapidity of adoption and associated abatement will not be sufficient to bridge the annual emissions gap forecast for 2030 [7]. As an alternative, scientists and governments agree that all aspects of human pollutant activity must be examined and low carbon alternatives researched and diffused during the next decade to compensate for this limitation [3].

Specifically, the United Nations Environmental Programme (UNEP) suggests that to bridge the gap, the world must combine existing technology with innovation. Doing so will support the UN

Px³ Ltd, Innovation Centre, University of Warwick Science Park, Warwick Technology Park, Gallows Hill, Warwick, CV34 6UW, United Kingdom

Sustainable Development Goal (SDG) [8] for climate action and drive behavioural changes capable of reducing societal emissions [7].

Considering the criteria, personal computing is a prime candidate technology for participation in this alternate sustainability strategy.

The rational being that as a mature technology, end user computing (EUC) generates 1% of global GHG annual emissions [1] This is caused by the yearly manufacturing of 460 million devices and the associated energy consumed by 4.2bn active users [1].

Current research indicates that this annual carbon footprint is 556,000,000 tCO_2e of GHG emissions. This is equivalent to 1.4bn fossil fuel car miles and requires a 2.8m km^2 forest the size of Argentina to sequester the pollution [1].

A further 1% is attributed to commuting to access IT (CAIT). Research indicates that as an average IT using commuters create 1,031 kgCO2e per year [48] travelling to access IT systems located within office buildings.

Legislation as a Sustainability Driver

Global environmental frameworks [9] protocols [10] and treaties [11] have subsequently generated regional and nation GHG abatement and reporting legislation [12-18], sustainable ICT purchasing policies [19-25] and manufacturing and use standards [26-40] designed to encourage organisations to adopt sustainable IT practices. However, research highlights that resistance factors, such as a lack of awareness, cause over one third of organisations to simply not take action [41].

From a global perspective, each nation experiencing such inertia misses an opportunity to bridge the emissions gap as the world continues to experience digitisation. As an example, the United Kingdom's (UK) Climate Change Act [12] includes an amendment to the Companies Act [13], ensuring that organisations operating in the UK are subject to mandatory GHG emissions reporting. Specifically, from April 2019, all organisations listed on the London Stock Exchange, all large unquoted companies and large Limited Liability Partnerships (LLPs), Government departments, non-ministerial departments, agencies and Non-Departmental Public Bodies must adhere to the legislation.

These organisations, known as the 'service sector', represent over 50% of the total national workforce with 10.74m working in large companies and 5.4m in public organisations [41, 42]. The sector consumes 32% of all UK electricity with 10.4% attributed to the use of IT solutions [41, 42].

Consequently, information technology (IT) is the UK service sector's third largest consumer of electricity behind lighting (14.5%) and cooling and ventilation (13.4%) [41, 42].

To directly address this growing GHG source, specific conditions are included within national and international legislation requiring EUC device procurement and subsequent operation to meet what are described as 'hard targets' [1, 22]. These include all future IT purchases to be accompanied by a scientific targets capable of supporting GHG abatement and net zero initiatives. In response, this could be as simple as selecting EUC devices proven to have a low carbon footprint driven by influences such as energy efficiency. The rational being that the concomitant GHG emissions would therefore be reduced cumulatively during the useful lifespan of the product.

Science Based Targets

However, associated resistance factors, such as incremental budget perception, are preventing almost one third of organisations to adopt meaningful sustainable IT strategies [41]. The cause being the time associated with identifying genuinely sustainable computer equipment is considered prohibitive when triangulated with the perceived positive environmental impact that such projects deliver [41]. Such friction causes inertia within an organisation's ability to balance the triple bottom line of profit, planet and people. In simple terms, if taking climate action is perceived to be too complex and too costly, even those organisations with mature corporate and social responsibility (CSR) and environmental, social and governance (ESG) strategies fail to form truly science based targets for IT [41]. The complexity and confusion is caused by associated carbon footprint information required to enable valid environmental buying criteria being elusive, confusing and unintentionally misleading [1]. As an example, almost three quarters of companies note that in order to identify EUC device GHG emissions caused by electricity consumption, they use two methods [43]. Firstly, 39% convert the publicly available energy efficiency benchmark data to GHG emissions using government published electricity conversion factors. Secondly, 35% rely upon the manufacturer published GHG use phase emissions values to populate the reports.

In both cases, research identifies that the resulting GHG emissions values are underestimated by 30% and cause substantiated abatement opportunities in excess of 55% to be overlooked [2].

The error is caused because the energy efficiency benchmark data used as the source for both approaches only measures and reports 'no-user present' power draw and electricity consumption associated with low power modes such as 'off', 'sleep' and 'idle' [2]. Consequently, the impact of user interaction upon the computer's energy consumption performance as the device carries out useful work is excluded from any calculations. During this 'active' mode, the EUC device will consume additional electricity as it processes requests, seeking data from storage, memory, or cache and populating the screen with images. Additionally, depending upon variables such as the type of operating system (OS) and chipset, EUC device energy efficiency varies considerably during the active mode [2].

As such, the lack of clear understanding of such environmental performance metrics causes the setting of science based targets to become unfeasible [2]. As an example. the impact not only affects presales device selection but also post purchase GHG quantification and reporting. As both metrics are essential to assessing the successful achievement of sustainability 'hard targets' and GHG accounting, the importance of accessing accurate values becomes intensified. Considering that GHG accounting protocol for scope 2 (electricity purchased for consumption) emissions requires quantities of carbon dioxide equivalents (CO_2e) to be calculated as 'neither over nor under actual emissions' [45] inaccuracies of 30% cannot be ignored.

Accurate IT GHG Quantification

In order to overcome the complexity and inaccuracy associated with quantifying EUC device emissions [1, 2, 41, 42, 43, 44, 46, 48], Px^3 utilises several unique methodologies conceived during PhD and ongoing field research. One example is the Px^3 Device Use Phase Analysis (DUPA™) benchmark that bridges the information void by generating data highlighting energy performance in the field.

Specifically, the field measurement process accurately captures power draw (watts) and energy consumption values (kilo-watt hours) for EUC devices during the active mode. Two sets of data are produced during the comprehensive analysis, proven to be accurate within +/- 0.1%.

The first data set being power demand when conducting common user interactions such as productivity tasks (e.g. email and application access), content streaming and video conferencing.

The second data set includes real world user scenarios such as energy consumption during a working day that reflect accurately how a device performs when used in a business environment.

Both sets of data are published in the associated Px^3 Device Use Phase Analysis (DUPA™): Active Mode and Use Phase Energy Consumption Measurement Technical White Paper.

Equipped with this valuable data, commercial and public sector organisations are able to quantify accurate use phase GHG emissions in order identify EUC devices that can support sustainability strategies via the abatement of scope 2 emissions.

As such, bridging the information void generates 'real world data' that enables:

- Sustainable low energy EUC device selection criteria to create procurement programmes that are both simple and meaningful [1, 46]
- Electricity cost savings to be identified in order to support sustainability projects and break resistance barriers [41, 42]
- Quantification of all scope 2 and 3 IT related EUC GHG emissions to become simple, accurate and specific [1, 2, 41, 42, 44]
- Science based targets for climate action to be formed and monitored that withstand scrutiny to support hard targets required for a net zero future [1]
- Scope 2 GHG EUC device accounting and carbon footprint reporting to become accurate in order to comply with accounting protocol [45] and associated legislation [12-18]
- Accurate EUC device GHG emissions quantification and equivalents to be included with confidence within CSR and ESG strategies to improve stakeholder engagement [1, 41, 42, 46]

Scope 2 and 3 IT Related Greenhouse Gas Abatement

Ahead of exploring real world examples determining how sustainability strategies reduce IT related carbon footprint a brief overview of GHG accounting and categorisation is outlined as follows. The rationale being that when discussing various 'scopes' the values attributed to abatement become clear.

Carbon dioxide equivalent (CO_2e) is the accounting unit that represents a unified value for all of the greenhouse gases. The associated accounting framework called the 'Greenhouse Gas Protocol, A Corporate Accounting and Reporting Standard,' [45] offers a step-by-step guide for organisations wishing to quantify and report GHG emissions.

Including accounting for CO_2, CH_4, N_2O, HFCs, PFCs, SF_6 and NF_3 using the CO_2e unit, the objective is to ensure organisations follow a standardised and simplified approach when preparing consistent and transparent GHG inventories.

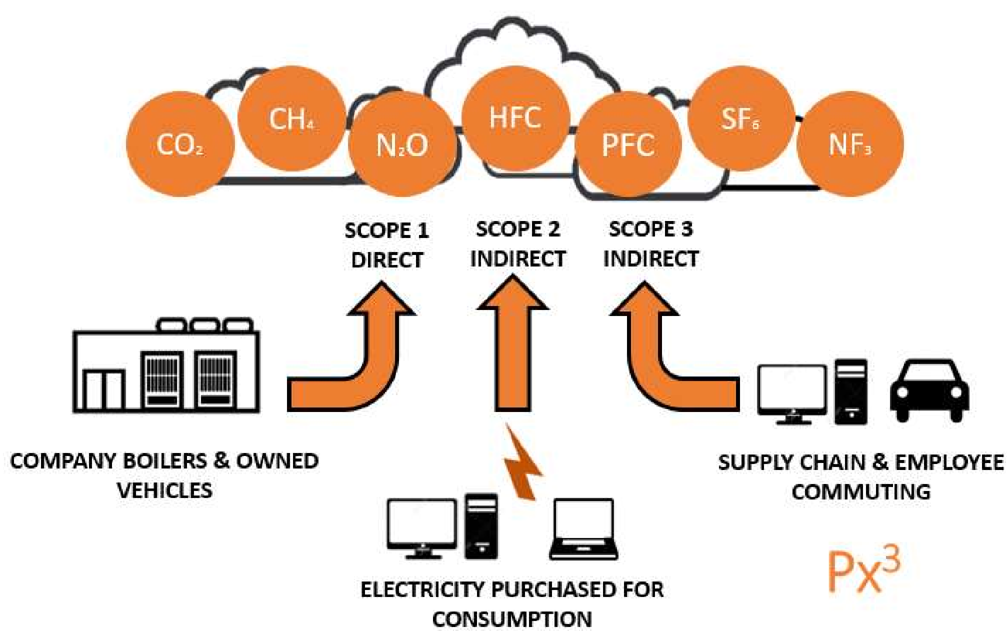
GHG emissions sources are categorised into three 'scopes' (see figure 4) to identify direct and indirect pollution generated by company operations.

- Scope 1 encompasses direct GHG emissions that occur from sources owned or controlled by the organisation. This includes emissions from company boilers and organisation owned vehicles or from chemical processing equipment.

- Scope 2 encompasses indirect emissions from electricity purchased and consumed by the organisation. In the context of IT, this includes the electricity consumed during the EUC device use phase and by data centres and networks.

- Scope 3 encompasses other indirect GHG emissions generated by activities undertaken by the organisation but not owned or controlled by the organisation. This includes activities such as the overall supply chain including IT hardware and services and employee commuting.

Figure 1 – GHG emissions by scope



Px³

As previously noted, countries are subject to global GHG reporting legislation [10-18]. This flows down to companies operating within national business markets. As an example, in the UK the necessity to report GHG emissions using the accounting protocol [45] is mandatory for all organisations listed on the London Stock Exchange, all large unquoted companies and large limited liability partnerships (LLPs), government departments, non-ministerial departments, agencies and non-departmental public bodies [14]. In relation to large companies, this is not restricted by the number of employees and companies can be judged as large if they meet any two of the following criteria [14]:

- turnover (or gross income) of £36 million or more
- balance sheet assets of £18 million or more
- 250 employees or more

Additionally, from an international perspective, public sector organisations are specifically required to adopt sustainable practices in relation to IT [20-25] that include the reduction of scope 2 and 3 emissions.

In all instances, beyond wishing to operate responsibly and tackle climate change, participation is rising because organisations are also beginning to understand that positive environmental policies create a positive influence upon both brand, prospective stakeholders and employees. As an example, 64% of millennials will not work for companies with weak CSR policies and 83% will stay with companies that contribute to environmental and social causes [41]. The opinion is further substantiated by research determining that our carbon footprint is high upon personal agendas. In a global and national study, when asked, 'If 10 is the highest importance, how important to you is reducing your carbon footprint?' the average response among employees was '8' [43, 48].

Consequently, over 60% of organisations have a CSR strategy designed to abate GHG emissions. Of these, 79% include a specific focus upon reducing IT related pollution [41].

To enable such strategies, Px³ research focuses upon the abatement of IT related emissions in both scope 2 and 3. This includes reducing scope 2 use phase electricity consumption via the identification of energy efficient equipment. The reduction of scope 3 emissions via the identification of IT hardware with a low embodied emissions value and the justification of lifespan extension strategies such as re-purposing to drive displacement. Plus, determining the impact of remote working solutions that reduce scope 3 commuting to access IT (CAIT) GHG emissions.

This is important because, combined, research determines [1] these IT related pollution sources generate 5% of global GHG emissions. As an analogy, a forest the size of Canada and Greenland is required to sequester the pollution created by the way we work today.

Real World Examples

Further to the science [3, 7] legislation and policies [12-25] and accounting protocol [45] driving the need to identify sustainable IT strategies, the following scenarios offer real world examples of the associated positive environmental impacts achieved. These examples include displacement, remote working and selecting energy efficient devices. By relating IT related GHG emissions to familiar business scenarios, stakeholders wanting to bridge the emissions gap with IT related climate action can recognise the potential and embrace the opportunity. Each scenario reflects a real event proving that the results can be applied to any public or private sector organisation.

Electricity (kWh), GHG emissions (kgCO_2e) and, where relevant, financial (£GBP) values are included. Additionally, analogous values are also noted in the form of equivalent fossil fuel car miles and forest area required to sequester the pollution created by EUC operations. The rationale is to transfer meaning from a familiar object to unfamiliar values such as GHG quantification [1, 46]. As such, the 'aha' moment of consumer psychology is achieved regardless of the stakeholder's technical appreciation of either GHG emissions, climatology or computer science [46].

Two further metrics are also highlighted where relevant. These include a per capita EUC device GHG ratio known as the Px³ employee vehicle equivalent (EVE™) [1, 46] and the Px³ Silent Sole™ use phase energy efficiency EUC device certification [1]. The EVE ratio [46] achieves two outcomes. Firstly, it acts as a base line that when historically compared, enables organisations to swiftly appreciate if their EUC device emissions have proportionately improved year on year regardless of employee number expansion or contraction. Secondly, by creating an individual EUC device carbon footprint indicator, employee personal interests, needs and viewpoints are appealed to regardless of their job role or involvement with sustainability policy setting. The rationale being, that each employee becomes aware of the impact of EUC operations and has the ability to reduce the ratio by requesting and using an energy efficient device [46] or increasing remote working [48]. The ratio is created by simply dividing the 'EUC Use Phase Related GHG Emissions Vehicle Miles Equivalent' by the 'Number of EUC Device Users'. As an example, if the vehicle mile equivalent pollution for EUC use phase energy GHG emissions is 26,000 and the number of employees 1,000 then the result is 1:26. This means that for every EUC device user the equivalent of 26 miles of vehicle pollution is generated every year.

The Px³ Silent Sole certification [1] represents the number of human steps required to expend the equivalent amount of energy as consumed by the EUC device in one business day (9am to 5pm). The electricity consumption is converted to human steps for two reasons. Firstly, to achieve a universal constant as both measures are quantified in the same manner regardless of geography. As an example, if GHG emissions were used as an alternative to equivalent steps, the results would differ from country to country. This is due to the differing percentages of green, renewable and fossil derived energy that supply each nation's electricity grid and therefore affect the carbon intensity of the electricity consumed. Secondly, it is used to create a tangible analogy that can be instantly recognised and understood by all. As such, the concept of equivalent steps demystifies the often complex unit of 'kWh' applied to electricity consumption. Colour too plays a key role in certification. A green 'Silent Sole' indicates that the device is among the most efficient tested within its classification (e.g. notebook, tablet or desktop computer). Whereas amber or red indicates the device has not reached the 'green' classification threshold. In summary, devices achieving less than 1500 equivalent steps receive a green Silent Sole. Devices achieving between 1501 and 2000 equivalent steps receive an amber certification, whilst red is awarded for energy equivalent to in excess of 2001 steps.

Scenario 1 – Quantifying the Positive Environmental Impact of Displacement Strategies

Displacement strategies involve the re-purposing of computer hardware. Doing so extends the existing device useful lifespan and consequently causes the manufacturing (embodied and transport) emissions of a potential replacement device not to be required. This is important as research highlights that in excess of 50% of a device's carbon footprint is created during the manufacturing phase [1].

In order to determine the positive environmental impact of displacement four key metrics must be considered. Firstly, the scope 3 (supply chain) GHG emissions (kgCO_2e) attributed to the replacement device. Secondly, the energy consumption (kWh) and concomitant scope 2 (electricity purchased for use) GHG emissions of both the existing and new device. Thirdly, the duration that the re-purposed device will assume its new role before recycling. Fourthly, the scope 3 (supply chain) GHG emissions generated by recycling existing equipment.

In this real life example studied as lifecycle assessment (LCA) field research for IGEL, 3,150 Dell OptiPlex 7010 small format desktop computers are repurposed to create thin client devices. The purpose is to create an 'office in a box' secure remote working solution for financial services employees in a UK company. The alternative to displacement was to purchase a new HP T640 thin client device and recycle the existing computers. As such the results are as follows.

Projected Impact of New Equipment

The proposed HP T640 has an embodied emissions value of 115 kCO2e per device. Consequently, the total carbon footprint created by the supply of 3,150 new devices is 362,250 kgCO_2e.

Measured for energy consumption in the workplace using the Px^3 Device Use Phase Analysis (DUPA) methodology, the HP T640 thin client consumes 17.52 kWh annually per unit. As the devices would prospectively all be located in the UK, concomitant scope 2 emissions are quantified as 3.72 kgCO_2e per unit. In total the entire new thin client estate will consume 55,188 kWh generating 11,718 kgCO_2e annually.

Proposed for a 5-year useful lifecycle, the total carbon footprint created by the purchase and use of the new product is 58,590 kgCO2e of scope 2 emissions for the duration and 362,250 kgCO_2e scope 3 emissions incurred in year 1.

Should replacement occur, the existing hardware will require recycling. The additional impact of this must be added to the overall footprint of the replacement strategy. Calculated as 0.75% of the original embodied GHG value of the original Dell device, this value equals 5,143 kgCO_2e.

Therefore, from an environmental perspective, new hardware will create a 5-year total impact of 425,983 kgCO_2e. This is equivalent to emissions caused by driving 1,543,640 miles and requires 511 acres of mature forest to sequester the pollution.

From a cost perspective, the purchase value applied to the new HP T640 is £300 per unit. As such, the procurement cost of the entire new estate is set for example purposes at £ 945,000. Additionally, utility cost for the lifecycle period will be £47,462 based upon the average price per kWh of electricity being £0.172.

As such the total cost of ownership for the newly acquired thin client estate during a 5-year period is £992,462.

Projected Impact of Displacement

The Dell OptiPlex 7010 SFF devices already exist. As such, the scope 3 GHG emissions of 218 $kgCO_2e$ per unit have already been accounted for 5-years previously when first purchased. Consequently, the total supply chain carbon footprint caused by retaining the devices is zero ongoing.

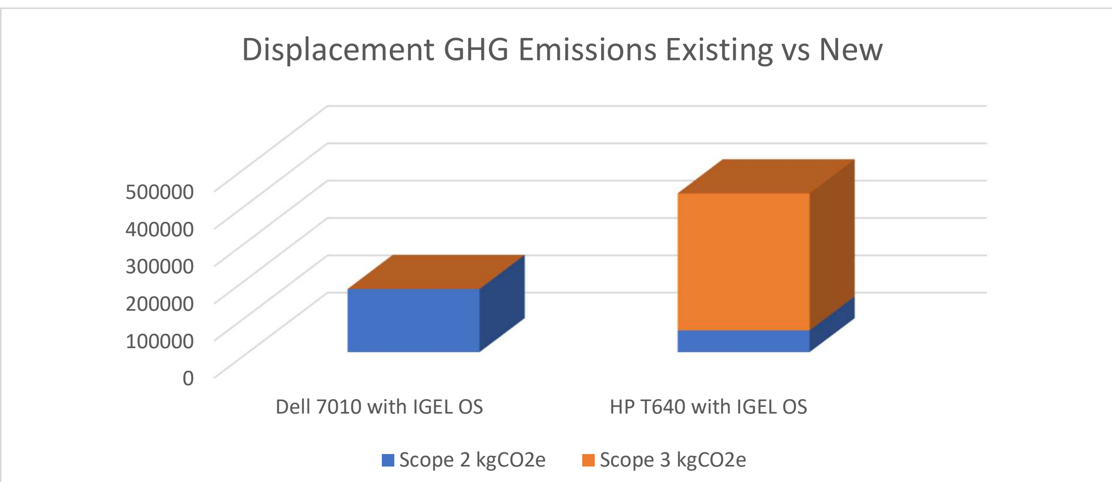
Measured for energy consumption in the workplace using the Px³ DUPA methodology, the Dell OptiPlex 7010 SFF desktop computer with the new IGEL thin client operating system (OS) installed consumes 22% less energy than when operating the original Microsoft Windows 7 Pro OS. Consequently, as a re-purposed thin client computer the device consumes 50.81 kWh annually per unit. As the devices will be located in the UK, concomitant scope 2 emissions are quantified as 10.79 $kgCO_2e$ per unit. In total the entire re-purposed thin client estate will consume 160,052 kWh generating 33,989 $kgCO_2e$ annually.

Proposed for a 5-year useful lifecycle extension, the total carbon footprint created by the retention and re-purposing of the Dell products is 169,945 kgCO2e of scope 2 emissions and 0 kgCO2e scope 3 emissions. This is equivalent to emissions caused by driving 615,832 miles and requires 204 acres of mature forest to sequester the pollution.

From a cost perspective, no purchase value is applied to existing Dell OptiPlex 7010 SFF computers as these have already been financially accounted for in year one of purchase. However, the procurement cost of 3,150 IGEL OS perpetual licenses is for example purposes £315,000. Additionally, utility cost for the same period will be £ 137,644 based upon the average annual price per kWh of £0.172.

As such the total cost of ownership attributed to the displacement strategy is £452,644.

Figure 2 – Displacement GHG Emissions Existing vs. New

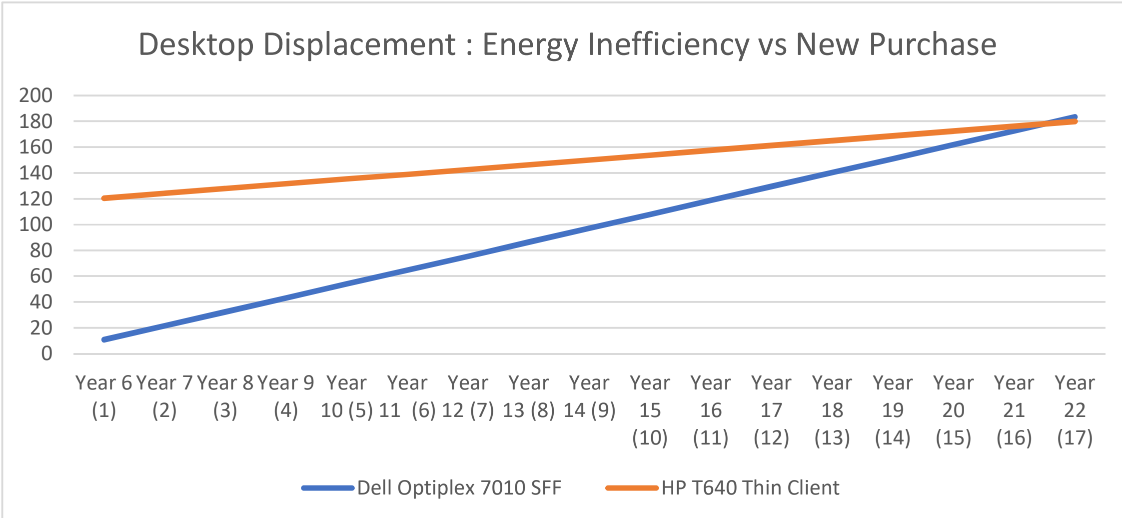


Quantified Displacement Environmental Gains

As emphasised by figure 2, displacement delivers a 60% reduction in carbon footprint across a 5-year period. Specifically, delaying the purchase of new equipment reduces combined scope 2 and 3 potential emissions from 425,983 $kgCO_2e$ to 169,945 $kgCO_2e$. This is equivalent to avoiding 927,808 car miles and freeing the sequestering capacity of 307 forest acres.

It is notable that whilst the energy consumption of the existing Dell device is 65% higher than the proposed replacement device, the impact of the manufacturing emissions far outweighs the energy efficiency gain delivered by the new computer. This is perhaps best highlighted by figure 3 indicating that in order to balance the embodied impact with efficiency, 17 years of use must pass.

Figure 3 – Energy inefficiency versus new device efficiency



Whilst the quantification of the 'planet' impact is essential to substantiation of environmentally focused strategies, research highlights that financial cost is the dominant barrier to the diffusion of sustainable IT [41]. As such it is reasonable to also include a 'profit' impact metric to ease the resistance and gain wider stakeholder support from budget holders such as the Chief Financial Officer (CFO).

In this example, selecting a displacement policy reduced the overall project costs by 55% from £992,462 to £452,644. Consequently, by adopting a sustainable approach to thin client computing the company saved £539,818 during the 5-year period.

To complete the triple bottom line determination, a 'people' quantification can be achieved using the Px^3 per capita EVE ratio. Following the replacement device policy, the financial services company would create a ratio of 1:98 meaning that for every IT user, pollution equivalent to driving 98 car miles each year will be produced. However, adopting the displacement strategy this is reduced by 60% to 1:39 meaning that for every user the emissions equivalent of 59 car miles are annually.

Displacement Conclusion

As scientifically proven, displacement is the best policy for delivering end user computing sustainability strategies.

In this example by re-purposing the existing Dell desktop devices to thin clients using the IGEL OS enabled total GHG emissions for a 5-year period are reduced by 60% and project costs by 55%.

In conclusion, the decision to proceed with displacement is substantiated from an environmental and financial perspective. Specifically, the results highlight that sustainable IT strategies are capable of supporting both climate change action and being 'self-funding' if approached from a science based target perspective.

Px³

Scenario 2 – Quantifying the Positive Environmental Impact of Thin Client Remote Working Strategies

Remote working strategies involve the ability to enable employees to work from home or a similar location that is away from an organisation's premises. In the context of the same financial services organisation highlighted in scenario 1, the 'office in a box' solution enabled staff to work from home five days per week as an extreme. Consequently, associated scope 3 commuting to access IT (CAIT) emissions were abated by staff not commuting to access IT (CAIT) located at offices across the UK.

However, empirical research [48] determines that the average number of home working days is two per week and that the average annual scope 3 employee commuting footprint is 1,031 kgCO2e per year.

In order to determine the positive environmental impact of remote working strategies three key metrics must be considered. Firstly, the scope 3 (employee commuting) $kgCO_2e$ attributed each employee. Secondly, the energy consumption (kWh) and concomitant scope 2 (electricity purchased for use) GHG emissions value equipment located within the office and remotely. Thirdly, the scope 2 incremental data centre electricity consumption required by the new remote working platform.

As before, in this real life example studied as field research for IGEL, 3,150 Dell OptiPlex 7010 small format desktop computers are repurposed to create thin client devices. The purpose is to create an 'office in a box' secure remote working solution for employees at a financial service company in the UK.

Quantified Impact of Office Based Working

When working at company offices, the employees use a combination of the Dell OptiPlex 7010 small form factor desktop with a Microsoft Windows operating system and a 24" monitor.

Measured for energy consumption in the workplace using the Px³ Device Use Phase Analysis (DUPA) methodology, the desktop computer and monitor combination consumes 86.03 kWh annually per user. As the devices are located in the UK, concomitant scope 2 emissions are quantified as 18.27 $kgCO_2e$ per user. Before creating remote working capabilities, the entire desktop computing estate consumed 270,995 kWh generating 57,540 $kgCO_2e$ annually.

Based upon IT users commuting to the office 5-days per working week, the annual scope 3 CAIT emissions are 5,412,750 $kgCO_2e$.

From an environmental perspective, permanent office based working will create an annual total impact of 5,470,290 $kgCO_2e$. This is equivalent to emissions caused by driving 19,822,764 miles and requires 6,495 acres of mature forest to sequester the pollution.

Quantified Impact of Remote Working

When working remotely, the employees use a combination of the Dell OptiPlex 7010 small form factor re-purposed thin client with an IGEL operating system and a 24" monitor.

Measured for energy consumption in the workplace using the Px³ Device Use Phase Analysis (DUPA) methodology, the thin client and monitor combination consumes 71.69 kWh annually per user. As the devices are located in the UK, concomitant scope 2 emissions are quantified as 15.22 kgCO2e per user. Based upon two days remote working per week, the entire thin client estate consumes 90,329 kWh generating 19,179 kgCO2e annually.

As the remote users also require access to virtualised desktops located within a data centre, this will increase data centre electricity consumption. Px[3] research determines that this additional virtualised desktop infrastructure (VDI) requirement requires 20.85 kWh per user annually based upon a two day per working week remote access policy. Consequently, an additional energy consumption value of 65,664 kWh will create scope 2 emissions of 13,943 kgCO_2e annually.

From an environmental perspective, the remote working solution will create an annual total impact of 33,122 kgCO_2e. This is equivalent to emissions caused by driving 120,025 miles and requires 39.75 acres of mature forest to sequester the pollution.

Quantified Remote Working Gains

Based upon a blend of three office working days and two remote, the resulting environmental impact is determined by the scope 2 energy consumption and scope 3 employee commuting emissions. As such, three days of office desktop electricity consumption plus two days of remote consumption will require an annual energy value of 318,570 kWh. It is noticeable that despite the 22% energy consumption reduction caused by the IGEL OS within the thin client estate, this is an increase of 18% energy consumption overall. The rise is caused by the additional data centre infrastructure requirement to support the new VDI solution as noted. The environmental impact of this produces two results depending upon the location of the data centre.

If the data centre is situated on premises and connected to the UK national grid, then the associated scope 2 emissions will generate 67,642 kgCO_2e annually. This is because the carbon intensity is dictated by the percentage of renewable energy supplying the grid.

However, if the data centre is located in 'the cloud', such as the Google Cloud Platform, the two outcomes will be observed. Firstly, as such data centres are considered a service the scope 2 emissions shift to become scope 3 emissions. Additionally, as the data centres are operated on a carbon neutral basis supplied by 100% renewable energy and offset then the accounting value of the scope 3 emissions is determined as 0 kgCO2e. As such, in this scenarios the scope 2 emissions for the new remote working solution decline 21% from 67,642 kgCO_2e to 53,703 kgCO_2e.

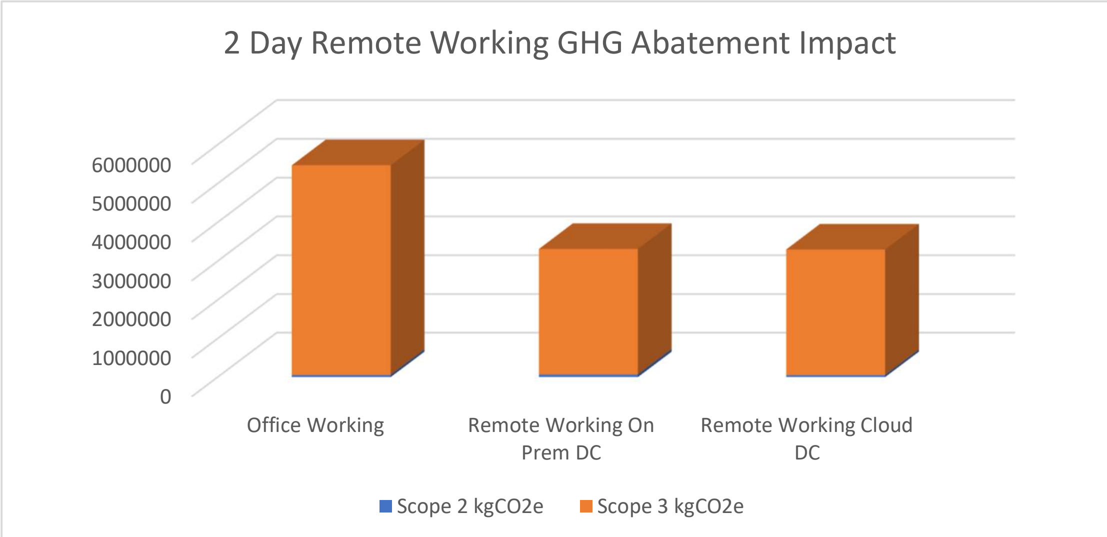
In both instances, the reduction of commuting emissions delivered by the remote working solution creates a significantly positive environmental perspective. Transitioning from 5-day commuting weeks to 3-day the scope 3 CAIT emissions are reduced by 40% from 5,412,750 kgCO_2e to 3,247,650 kgCO_2e annually.

Remote Working Conclusion

As highlighted in figure 4, the adoption of remote working solutions delivers substantial GHG abatement opportunities. Specifically, when adopting a two-day home working policy supported by re-purposed thin clients and carbon neutral data centres, total IT related annual emissions for the 3,150 financial services employees will reduce by 40% from 5,470,290 kgCO_2e to 3,301,353 kgCO2e. Such abatement is equivalent to avoiding the pollution 7,859,606 created by driving car miles and releases the sequestering capacity of 2,602 mature forest acres.

Additionally, the associated scope 2 and 3 combined per capita EVE ratio will reduce from 6293:1 to 3798:1. This means that for every IT user, pollution equivalent to 2,495 car miles will be avoided every year.

Figure 4 – Office Versus Remote Working Comparisons



Scenario 3 – Quantifying the Positive Impact of Low EUC Device Use Phase Electricity Consumption

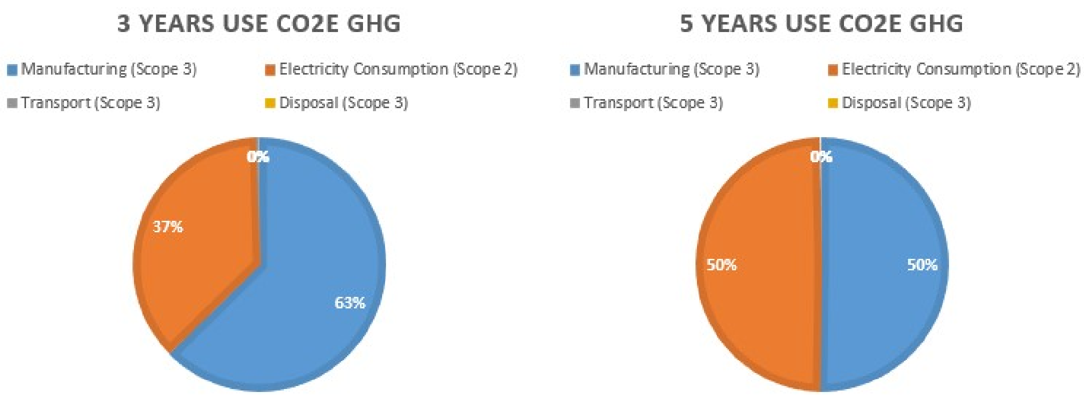
As indicated, embodied emissions and use phase energy emissions contribute to the majority of an EUC device's carbon footprint. Each source is accounted for as scope 2 (electricity purchased for use) and scope 3 (supply chain) respectively [45]. Often represented as a total figure in manufacturer carbon footprint reports, quantification of both measures in isolation is important if true comparison is to be achieved.

As an example, one computer may appear to have a lower carbon footprint than another simply because less years of electricity consumption are included in the LCA calculation. This is best demonstrated by the lack of uniformity among manufacturer desktop computer reports. Microsoft includes a 3-year lifetime within the total carbon footprint, Apple and Dell select 4-years and Lenovo, HP and Pure Computer 5-years [1].

As such, the impact of this decision adds two extra years of electricity consumption to the product carbon foot. Figure 5 highlights this influence, showing the Microsoft Studio 2 published carbon footprint as 601kgCO_2e with 3-years of use, versus 749kgCO_2e when harmonised to 5-years. As such the proportionate representation of scope 2 energy emissions rises from 37% to 50% during the device lifespan having increased the total carbon footprint by 25%.

Understanding the effect of electricity consumption upon the carbon footprint is essential for all sustainable device procurement strategies. Electricity generation and supply remains 67% reliant upon combustible fuel despite efforts to transform to sustainable sources [6]. Consequently, energy generates 31% of global GHG emissions due to high levels of carbon intensity with electricity specifically producing 31.1bn tCO2 annually [6, 47]. Against a backdrop of global digitisation, increased electricity demand is driving the highest annual increases for more than a decade. As an example, recent annual consumption growth alone eclipsed the equivalent total emissions created by international aviation [6].

Figure 5 – Harmonising use phase energy consumption lifespan



Understanding the effect of electricity consumption upon the carbon footprint is essential for all sustainable device procurement strategies. Electricity generation and supply remains 67% reliant upon combustible fuel despite efforts to transform to sustainable sources [6]. Consequently, energy generates 31% of global GHG emissions due to high levels of carbon intensity with electricity specifically producing 31.1bn tCO_2 annually [6, 47]. Against a backdrop of global digitisation, increased electricity demand is driving the highest annual increases for more than a decade. As an example, recent annual consumption growth alone eclipsed the equivalent total emissions created by international aviation [6].

As such, it is perhaps unsurprising that the majority of sustainable device procurement programmes focus upon purchasing energy efficient devices [43]. The rationale being that as the average device retention rate is between 3 and 5 years [1], then during each year of use, the organisation can rest assured that they are achieving some level of operational efficiency.

Specifically, research indicates that over 70% of organisations utilise third party certification label (TPCL) programmes, such as Energy Star, to identify energy efficient devices [43]. The strategy certainly sets a threshold for anticipated electricity consumption as such TPCL schemes are controlled by strict test set up and conduct benchmark procedures [37].

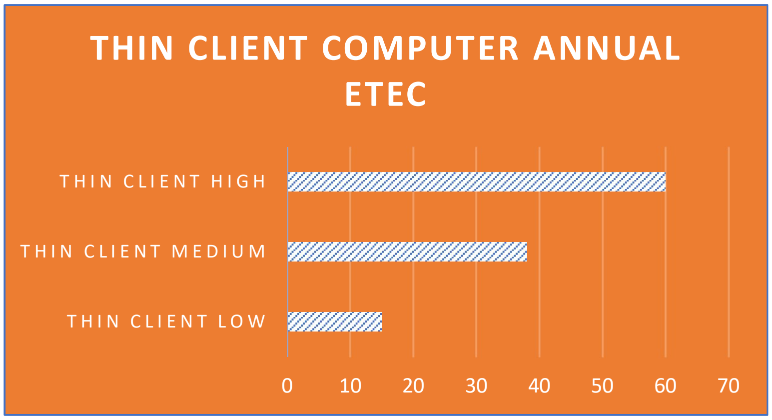
However, relying solely upon 'non-user present' benchmarks and associated identifying badges creates the potential for sustainable EUC device procurement schemes to significantly underperform [2].

This limitation is caused by two influencing factors that are often overlooked and discussed in the following two sections.

Oversight A: Range of Typical Energy Consumption Efficiency

The first issue arises simply because of the range of efficiency available by selecting EUC devices within the same category such as 'thin clients'. As an example, figure 6 highlights the Energy Star annual typical energy consumption values of commonly used business thin client computers. The low (L), medium (M) and high (H) electricity consumption examples illustrate that even within one device category the range of energy efficiency is 0-300%, rising from 15kWh to 60kWh per year.

Figure 6 – Energy Star Annual Typical Energy Consumption (kWh) Range Example



As such, it is reasonable to state that simply selecting an EUC device because it has an energy efficiency logo or certification is certainly an appropriate baseline. However, it does not ensure the maximum potential of a sustainable procurement policy if the electricity consumption values are not compared.

Oversight B: Use Phase Energy Efficiency in Business

The second issue arises because EUC device energy consumption increases when operated by a user [2]. As such, real world annual electricity consumption will not reflect the Energy Star published values [2].

The reason for this is easily explained. As previously indicated, the Energy Star energy consumption benchmark is designed to create a level playing field against which all new EUC devices can be tested for presale energy efficiency. The term 'presale' is used to describe the process as no user interaction is involved during measurement. Instead only low power, no user present modes are measured under highly accurate and well defined test set up and conduct conditions. During the benchmark power draw, measured in watts (W), is noted for operational modes including off, sleep, and idle. The results are then applied to an equation that generates a fixed annual typical energy consumption (TEC) value measured in kWh.

To achieve this, time spent during one year in each mode is applied to the equation. This is called 'mode weighting'. For desktop and thin client computers, the mode weightings are Off=15%, Sleep=45%, Long Idle=10% and Short Idle=30%. As such, the TEC equation is expressed as follows, where P equals 'power' and T equals 'time':

$$\text{e}TEC = 8760/1000 \times (POFF \times TOFF + PSLEEP \times TSLEEP + PLONG\_IDLE \times TLONG\_IDLE + PSHORT\_IDLE \times TSHORT\_IDLE)$$

The equation uses all 8760 hours in a year divided by 1000 to create a kWh value. In doing this it is confirmed that the 'no user present' modes apply for the entire year.

Therefore, the TEC value can only act as a real world estimation of energy consumption if a user never operates the computer.

In reality, suggesting that business computers are purchased and never operated is counterintuitive as they are designed for human productivity. Consequently, organisations must examine energy consumption performance in the field if an accurate determination of energy efficiency and electricity consumed during working hours is to be attained. Px³ measures EUC devices for energy consumption in business environments using the DUPA ™ methodology. Created during PhD research conducted under supervision of the world's leading scientific universities [1], the results enable organisations to truly select devices with the lowest environmental impact during the use phase. This is vital to climate action. This is because research substantiates that even devices exhibiting a lower published Energy Star TEC value may exceed the energy consumption of a device with a higher TEC value when used in a business environment [2]. This is directly attributed to specification aspects such as how the operating system interacts with components and applications causing more or less power draw [2].

Consequently, even organisations practising energy efficient device procurement that includes using the TEC to examine beyond the attainment of a TPCL badge, may inadvertently overlook efficiencies of up to 55% if performance in the field is not considered [2].

Energy Efficient Device Comparison

To explore the significance of including active use energy consumption to identify energy efficient EUC devices and sustainability strategies, the following hypothetical scenario expresses the gains that can be achieved by an organisation. To allow for extrapolation, it is assumed that employees work for 232 days per year in line with government guidance [1].

All kWh values used in the example are extracted from real life measurements determined during the Px³ DUPA process. Values used for the cost of commercial electricity is an average appropriate for the year of publication.

Organisation XYZ is proposing to purchase 1,000 thin client computers to support a call centre. The rationale is that the work force consists of a high number of contractors that require access to systems but will not regularly use the same device. The organisation has decided that sustainability is a key criteria moving forward and as such energy efficient devices must be identified to support science based targets. The organisation's legacy procurement policy required the 'purchase of devices bearing the appropriate energy efficiency third party certification label (TPCL)'. However, as part of a drive to reduce scope 2 GHG emissions and meet new legislation, the new policy now includes quantification of energy consumption during the use phase including user interaction.

IGEL OS HP T640 Thin Client Computer

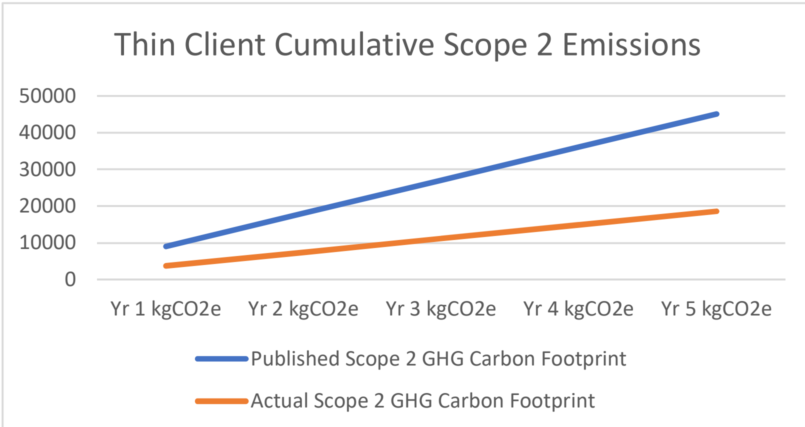
The IT and procurement teams have jointly identified the HP T640 thin client computer as a suitable small form factor device. Published energy consumption per year is 42.49 kWh generating a potential 9.02 kgCO_2e emissions per user. This indicates that the total scope 2 impact for a 5-year useful lifespan will be 45,110 kgCO2e. This is equivalent to the emissions produced by 163,464 car miles and requires 54 acres of mature forest to sequester the pollution.

From a financial perspective, at £0.14 per kWh of commercial tariff electricity consumed, the total cost of operating the 1,000 user thin client estate will be £29,743.

Engaging Px³, the company realises that this is simply a published estimation to accommodate for a variety of operating systems and is not applicable to the hours of use experience within their business. Consequently, measuring the IGEL OS variant of the HP T640 using the Px3 Device Use Phase Analysis (DUPA) methodology it is determined that the thin client will consume 59% less energy than estimated at 17.52 kWh annually per unit. As the devices would prospectively all be located in the UK, concomitant scope 2 emissions are quantified as 3.72 kgCO_2e per unit. This indicates that the total scope 2 impact for a 5-year useful lifespan will be 18,600 kgCO2e. This is equivalent to the emissions produced by 67,490 car miles and requires 22.3 acres of mature forest to sequester the pollution.

From a financial perspective, armed with the new active use figures, at £0.14 per kWh of commercial tariff electricity consumed, the total cost of operating the 1,000 user thin client estate will be £12,264.

Figure 7 – Cumulative 5-year scope 2 GHG use phase emissions comparison



Consequently, it is clear that in a business environment, the IGEL OS HP T460 thin client is a highly appropriate choice to support sustainable device procurement based upon use phase criteria. As figure 7 highlights, making this choice delivers low electricity consumption and concomitant scope 2 GHG emissions.

This is why the IGEL OS HP T640 thin client computer is awarded the highest 'green' level Px³ Silent Sole certification, requiring just 1,299 human steps per day to generate the equivalent computing use phase energy [50].

Scenario 4 – Examining CSR and ESG Inclusion to Maximise Stakeholder Engagement

The IGEL OS and associated hardware offerings are substantiated by this research as being highly suitable for sustainability strategies focusing upon the abatement of both scope 2 and scope 3 GHG emissions.

Specifically, the findings determine the IGEL OS is capable of driving 60% GHG when used in displacement strategies. 40% or more for remote working strategies and between 22% to 49% for projected energy consumption. As such it is reasonable to suggest that accurately quantifying an organisation's EUC GHG emissions is integral to setting a baseline, creating valid science base targets and measuring future abatement.

However, unless support for such an action resonates with all internal stakeholder groups, the activity may be short lived. As an example, research determines that the perceived impact of IT to tackle climate change diminishes among employees that are not involved with corporate and social responsibility (CSR) and environmental, social and governance (ESG) policy setting or subject to sustainability key performance indicators (KPI) [41].

Consequently, widening the appeal of IT sustainability strategies beyond management goals and key performance indicators to a personal 'IT user' level is essential to longevity and success [1, 42, 46]. To achieve this, ensuring that goals and success are communicated in a manner that can be both easily understood and appeal to personal interests, needs and viewpoints is important if sustainability focused behavioural changes are to be experienced across the whole organisation [1, 42, 46].

Two effective strategies to deliver simplicity and wider resonance include tangible analogy and personalisation. As previously explained and illustrated, the first is achieved by converting niche values such as GHG quantification units (CO_2e) to familiar values such as the pollution associated with car miles driven and forest acres required to 'clean' the emissions from our atmosphere via photosynthesis. The second is achieved by examining beyond the electricity utility cost reduction and GHG abatement that appeals to board level and management stakeholders and focusing the perspective to a single employee level using the Px^3 EVE ratio.

As such the following scenario acts as a summary of the information positioned previously by this research in relation to adopting sustainability strategies based upon IGEL software and hardware offerings. By doing so, it offers an example of potential content designed for a CSR or ESG annual report that includes a specific focus upon reducing IT GHG emissions in response to GHG abatement and reporting legislation [12-18] and sustainable IT purchasing policies [19-25].

In each section, stakeholder interest is noted to determine which groups are most likely to be attracted by the results beyond the sustainability and CSR/ESG teams producing the information.

Organisation XYZ has adopted a variety of IT sustainability strategies incorporating IGEL products. These include displacement, remote working and energy efficient device replacement.

The approaches support key sustainability criteria including the formation of science based targets [19-25] and accurate GHG reporting [45] capable of reducing scope 2 electricity purchased for use and scope 3 supply chain emissions. In turn, abatements in both areas substantiate commitment and ability to succeed in relation to the company CSR and ESG goals designed to address associated sustainable procurement policies [9-252] and climate change legislations [12-18].

Extracts generated by the policies may be condensed to appeal to stakeholders across the business in the following ways.

Cost Reduction (CEO, CFO, COO and IT management)
EUC device annual electricity consumption for the call centre was projected to as 212,450 kWh. The associated utility operational cost was expected to be £29,743.

Further to accurate quantification the EUC device annual electricity consumption projection is reduced by 49% to 87,600 kWh. The associated utility operational cost is £12,264.

Consequently, during the 5-year useful lifespan of the new low energy devices a total utility cost saving of £14,479 will be realised. This is directly attributed to the new low energy desktop computers requiring 124,850 less kWh of electricity to operate.

Additionally, by re-purposing our existing Dell 7010 devices to enable remote working an anticipated total project spend of £992,462 has been reduced to £452,644. Consequently, by adopting a sustainable approach to thin client computing the company has saved £539,818 across 5 years.

GHG Emissions Abatement (CEO, CFO, COO, IT management, Human Resources, Employees)
As a result of the actions noted in the financial summary GHG emissions have been significantly reduced.

Specifically, combined annual scope 2 emissions related to EUC device electricity consumption have reduced by 25% from 76,663 kgCO_2e to 57,423 kgCO_2e due to remote working and new device strategies. Scope 3 supply chain emissions of 362,250 kgCO_2e have been avoided due to displacement *strategies. And Scope 3 employee commuting emissions have been reduced by 40% from 5,412,750 $kgCO_2e$ to 3,247,650 $kgCO_2e$ avoiding 2,165,100 $kgCO_2e$ GHG emissions.*

Consequently, the sustainable transition has reduced predicted total IT related emissions from 5,851,663 $kgCO_2e$ to 3,305,073 $kgCO_2e$ creating an abatement of 43% and significantly exceeding the 30% abatement suggested by government policy [22].

The resulting abatement of 2,546,590 $kgCO_2e$ is equivalent to avoiding the pollution created by 9,228,112 car miles and releases the sequestering capacity of 3,055 acres of mature forest.

Per Capita EUC GHG Emissions Reduction (CEO, IT management, Human Resources, Employees)
Previously, the average annual IT related scope 2 and 3 GHG emissions value per employee was 1,140 $kgCO_2e$.

As a result, the per capita Px³ EVE ratio was 1:4131 meaning that for every staff member the equivalent pollution caused by driving 4,131 miles was being emitted into the atmosphere annually.

This year the average EUC GHG device emissions are 796 CO_2e meaning that the per capita Px³ EVE ratio has improved by 43% to 1:2884 meaning that for every staff member the equivalent pollution caused by driving 2,884 miles is now being emitted into the atmosphere annually.

Stakeholder Engagement Conclusion

As highlighted by this hypothetical outcome based on real world quantification, positioning the positive environmental impact in tangible and personal ways assists with stakeholder resonance. Board members and management tasked with strategy forming, results attainment and compliance will focus upon cost savings and environmental gains [1, 41, 42, 46]. Whilst human resources and employees, being the largest stakeholder group, can engagement via the personalised medium of the EVE ratio in the knowledge that sustainable device choice drives climate action [1,46].

Research Summary

As both legislation [12-18] and sustainable procurement and use policy [19-25] tighten causing a greater number of organisations to be subject to mandatory GHG emissions reporting and abatement, all sources of work related anthropogenic interference will be examined in the race to achieve net zero.

The UNEP indicates that to bridge the gap between success and failure, the world must combine existing technology with innovation in line with UN Sustainable Development Goals such as climate action [8].

Producing 1% of global GHG annual emissions [1] with as much 50% attributed to use [1] behavioural changes related to the displacement, selection and operation of EUC devices will become crucial to achieving such goals. The simple rationale being that as one one-hundredth of the total environmental problem it is hard to ignore such a rich source of abatement. Additionally, further environmental gains can be made via remote working solutions supported enabled by IT. As research indicates 40% reductions should be the minimum with up to 60% attainable [48].

This research offers substantiation to the significant abatements that could be achieved by adopting low carbon footprint EUC devices and sustainable IT strategies.

Specifically, the findings determine the IGEL OS is capable of driving 60% GHG when used in displacement strategies. 40% or more for remote working strategies and between 22% to 49% for projected energy consumption.'

Conclusion

As such, examining the results and examples presented by this research, organisations seeking to reduce IT related GHG emissions ought to be compelled by both the IGEL OS and associated thin client products. Exhibiting the ability to deliver displacement benefits stretching into 17 year periods and devices with category leading energy performance in the field organisations seeking to build science based targets to drive climate change action should investigate the diffusion of IGEL products.

 Px³ Ltd, Innovation Centre, University of Warwick Science Park, Warwick Technology Park, Gallows Hill, Warwick, CV34 6UW, United Kingdom

Px³

References

[1] Sutton-Parker, J. (2021), 'Can meaningful measurement of end user computing energy consumption drive human behavioural changes to abate greenhouse gas emissions?'. Warwickshire, England: The University of Warwick, Computer and Urban Science Department

[2] Sutton-Parker, J. (2020), 'Determining end user computing device Scope 2 GHG emissions with accurate use phase energy consumption measurement'. 1877-0509. Amsterdam, the Netherlands: Science Direct, Elsevier B.V.

[3] IPCC, Intergovernmental Panel on Climate Change. (2018), 'Global warming of 1.5^{o}C'. Switzerland: IPCC

[4] Department for Transport. (2019), 'Transport Statistics Great Britain 2019'. London: Crown copyright.

[5] Department for Transport. (2019), 'Vehicle Licensing Statistics'. London: Crown copyright.

[6] International Energy Agency. (2019), 'Global Energy & CO2 Status Report 2019'. Paris, France.

[7] United Nations Environment Programme. (2019), 'Emissions Gap Report'. Table ES1 Page 8.

[8] United Nations (2015b), United Nations, 'Sustainable Development Goals'. New York: United Nations.

[9] United Nations. (1992), 'United Nations Framework Convention on Climate Change (UNFCCC).' New York, USA: UN

[10] United Nations. (1997), 'Kyoto Protocol.' New York, USA: UN

[11] United Nations. (2015), 'Paris Agreement.' New York, USA: UN

[12] European Union. (2021), 'Governance of the Energy Union and Climate Action'. Brussels, Belgium: European Union

[13] HM Government. (2008), 'Climate Change Act 2008'. London, England: Crown copyright.

[14] HM Government. (2013) 'The Companies Act 2006 (Strategic Report and Directors' Report) Regulations).' Section 416 (c). London, England: Crown copyright.

[15] H.M. Government. (2021) 'Streamlined Energy and Carbon Reporting (SECR)'. London: Crown Copyright

[16] United States Environmental Protection Agency. (1990), 'Clean Air Act'. Washington, USA: US Congress

[17] United States Environmental Protection Agency. (2009),' Greenhouse Gas Reporting Program Methodology and Verification'. Washington: United States Congress.

[18] People's Republic of China. (1989), 'Laws on the Prevention and Control of Air/Water/Soil/Noise Pollution'. Beijing, China: National People's Congress

[19] European Commission. (2016), 'Buying Green, A handbook on green public procurement'. Brussels: European Union

[20] European Commission. (2021), 'EU green public procurement criteria for computers, monitors, tablets and smartphones'. Brussels: European Union

[21] European Commission. (2021), 'JRC Science for Policy Report Revision of the EU Green Public Procurement (GPP) Criteria for Computers and Monitors (and extension to Smartphones)'. Brussels: European Union

[22] Department for Food Environment and Rural Affairs. (2020). 'Greening government: ICT and digital services strategy 2020-2025'. London: Crown copyright.

[23] United States Federal Government (1993), Executive Order 12845 of April 21, 1993. Washington D.C. Federal Register Presidential Documents Vol. 58, No.77. Washington, USA: US Congress

[24] United States Environmental Protection Agency. (2020), 'Sustainable Marketplace, Greener Products and Services: Computers: Desktops, Notebooks (including 2-in-1 notebooks), Displays, Integrated Desktop Computers, Workstation Desktops, Thin Clients, and Slates/Tablets'. Washington: United States Congress.

[25] United States Environmental Protection Agency. (2020d), 'Environmentally Preferable Purchasing Program'. Washington: United States Congress

[26] European Union. (2009), 'Eco Design Directive 2009/125/EC of the European Parliament and of the Council of 21 October 2009: establishing a framework for the setting of eco design requirements for energy-related products'. Brussels: European Union

[27] European Union. (2009), 'Ecodesign Directive for Energy Related Products 2009/125/EC (ErP Directive) and Ecodesign regulation for external power supply EC No 278/2009. Brussels: European Union

[28] EU Commission, (2008) Regulation for Standby and Off Mode Power Consumption for Electronic Household and Office Equipment 1275/2008. Brussels: European Union

[29] United States Environmental Protection Agency. (2015), 'EPA Design for the Environment (DfE) Program's Cleaner Technologies Substitutes Assessment'. Washington DC, USA: USEPA

[30] International Standards Organisation. (2016), 'ISO 14040:2006 Environmental management, Life cycle assessment Principles and framework'. Geneva: International Organization for Standardization

[31] International Standards Organisation. (2016), 'ISO 14044:2006 Environmental management, Life cycle assessment Requirements and guidelines'. Geneva: International Organization for Standardization

[32] International Standards Organisation. (2018), ISO 14024:2018 Environmental labels and declarations. Type I environmental labelling. Principles and procedures.' Geneva: International Organization for Standardization

[33] International Electrotechnical Commission (IEC). (2011), 'Standard IEC 62301:2011 household electrical appliances measurement of standby power.' Geneva, Switzerland: IEC

[34] International Electrotechnical Commission (IEC). (2011), 'Standard IEC 62301:2012 desktop and notebook computers measurement of energy consumption.' Geneva, Switzerland: IEC

[35] The European Telecommunications Standards Institute. (2011), 'ETSI 103 199: Environmental Engineering (EE); Life Cycle Assessment (LCA) of ICT equipment, networks and services; General methodology and common requirements'. Sophia Antipolis, France: ETSI

[36] International Telecommunication Union. (2014), 'ITU-T L 1410 Methodology for environmental life cycle assessments of information and communication technology goods, networks and services'. Geneva, Switzerland: ITU

[37] Energy Star (2019), 'Computer Specification Version 8.' Washington DC, USA: Energy Star

[38] European Computer Manufacturers Association. (2019), 'ECMA-370 TED - The ECO declaration.' Geneva, Switzerland: ECMA.

[39] China Environmental United Certification Centre. (1993), 'The China Certification of Environmental Labelling (CCEL) Program.'

[40] China Environmental United Certification Centre. (1998), 'The China Energy Conservation Program (CECP).'

[41] Sutton-Parker, J. (2020), 'Quantifying resistance to the diffusion of information technology sustainability practices in United Kingdom service sector'. 1877-0509. Amsterdam, the Netherlands: Science Direct, Elsevier B.V.

[42] Dahlmann, F., and Sutton-Parker, J. (2020), 'The Cost of Running IT is the Next Sustainability Challenge'. Page 105. Paris, France: The Council on Business and Society.

[43] Sutton-Parker, J. (2021), 'Determining sustainable EUC device procurement and carbon footprint quantification practices in the UK Service Sector'. Warwickshire, England: The University of Warwick, Computer and Urban Science Department

[44] Sutton-Parker, J. (2021), 'Quantifying end user computing device use phase greenhouse gas emissions using analytics software.' Warwickshire, England: The University of Warwick, Computer and Urban Science Department

[45] World Business Council for Sustainable Development and World Resources Institute. (2004), 'The Greenhouse Gas Protocol. A Corporate Accounting and Reporting Standard'. Geneva, Switzerland and New York, USA.

[46] Sutton-Parker, J. (2020), 'All About EVE: Decoding personal IT sustainability success'. London, England: My Green Pod, The Guardian.

[47] United States Environmental Protection Agency. (2020), 'Global Greenhouse Gas Emissions Data.' Washington United States Congress

[48] Sutton-Parker, J. (2021), 'Determining commuting greenhouse gas emissions abatement achieved by information technology enabled remote working'. 1877-0509. Amsterdam, the Netherlands: Science Direct, Elsevier B.V.

[49] Px3 Ltd (2021). 'Device Use Phase Analysis (DUPA): Active Mode and Use Phase Energy Consumption Measurement Technical White Paper – Dell OptiPlex 7010 Small Form Factor'. Warwick, UK: Px3 Ltd

Px^3

About Px^3

Px^3 is a research focused IT consulting organisation specialising in sustainability and specifically the reduction of GHG emissions created by the way we work today. Our unique services enable IT manufacturers, commercial and public sector organisations to plan for and adopt sustainable IT that is good for the planet, people and productivity – hence our name.

The DUPA process is copyright of Px^3 Ltd as is the Silent Sole certification icon and EVE methodology. All three were developed during PhD research conducted under the supervision of the University of Warwick Computer and Urban Science faculty and the Warwick Business Schools Sustainability and Business faculty.

Electricity consumption values and government GHG conversion factors are accurate and current at time of measurement and subsequent publishing. Px^3 reserves the right to amend the DUPA efficiency RAG classifications as new and increasing energy efficient EUC device technology is developed and manufactured.

All measurements are conducted by qualified Px^3 research scientists and done so without bias in order to create science based data to support science based targets and sustainable behaviours. As such, energy efficiency classification is awarded solely upon data captured and results produced.

At Px^3 sustainability represents the principle of ensuring that our actions today do not limit the range of economic, social, and environmental options open to future generations. As such, it is Px^3's mission is to remove the CO_2e emissions equivalent of 100,000 cars from our atmosphere by 2050 via the diffusion of sustainable IT hardware and services.

The information included within this report is subject to the copyright of the author. Re-use and publishing in whole or extract for commercial gain must not be undertaken by any other party other than the author, Px^3 Ltd or IGEL and subject to permission and accurate reference. Academic reference may be granted further to consent of the author.

Px^3 Ltd
Innovation Centre
University of Warwick Science Park
Warwick Technology Park
Gallows Hill
Warwick
CV34 6UW
United Kingdom
01926 20623510
analysis@px3.org.uk
www.px3.org.uk

Px^3.org.uk
IT Sustainability Consulting